Productivity Effect of Piece Rate Contracts: Evidence from Two Small Field Experiments

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January 29, 2007

Abstract

I conducted two field experiments in a tree-thinning setting. In one experiment, farm workers were initially paid hourly wages, before a randomly chosen half were switched into piece rate pay. In the second experiment, workers were switched from hourly to piece rate pay all at once. The difference-in-difference and before-after estimators suggest that the productivity increase has a lower bound of 23 percent and an upper bound of 36 percent. Although the sample size is small, the estimates are statistically significant and robust. While the quality did not drop, the study highlights the measurement costs in setting up the right level of piece rates. I also provide evidence that high ability workers are attracted to piece rate contracts.

After noticing an agriculture employee working with only one hand, I asked him why he uses only one hand. The employee responded, 'Because I only get paid $7.63 per hour.' – Chad Anders

1. Introduction

Piece rate contracts are well understood theoretically by now.[1] Consistently estimating the incentive and selection effects require an identification strategy that strives to achieve an exogenous change in incentive pay method.

Using cross-sectional firm-level data requires the researcher to address the firms' choices of contracts; if there are unobserved firm characteristics that affect a firm's choice of contracts and the firm's productivity, the coefficient on the contract will be biased.[2] The same problem arises when using cross-sectional variations in contracts

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* I would like to thank Chad Anders for his excellent research assistance and Yakima Valley Orchards for their co-operation. I also benefited from comments of my colleagues.

1 See Lazear (1986) on the incentive and selection effects of piece rate contracts, Holmstrom and Milgrom (1992) for multi-tasking, Baker (1992) for performance measurements, Gibbons (1987) and Kanemoto and MacLeod (1993) for the ratchet effect.

2 A panel of firm-level data, by making firm fixed effects possible, helps to capture the time-invariant unobserved characteristics that affect both the choice of contracts and a firm's productivity. Doing firm-fixed effects, however, effectively kills the cross-sectional variation in contracts, and utilizes the time-

within a firm. Recognizing this problem, Paarsch and Shearer (1999, 2000) modeled the firm's choice and relied on a structural estimation method in order to consistently estimate the productivity effect of piece rate contracts in a tree-planting firm. The cost of a structural estimation, of course, is that one has to make a lot of assumptions on the players' preferences and the production technology.

An alternative way to achieve the variation is through a time-series change in pay scheme. Lazear (2000) got around the problems plaguing cross-sectional variation by exploiting worker-level data in an auto-glass installing firm that implemented a change from hourly wages to piece rate pay during a 19-month period. The change in the pay scheme allowed him to get a before-after estimate. Furthermore, the gradual introduction of the scheme allowed him to control for the other changes concurrent with the change in incentive scheme, such as possible management style changes and seasonal order fluctuations, making it a difference-in-difference estimator.

Probably the cleanest way to get an estimate of the productivity effect of piece rate contracts is to generate exogenous change in incentive plan achieved through what List (2004) called "framed field experiments." This paper is an attempt in this direction. I conducted randomized field experiments in a tree-thinning setting in Central Washington State, switching a randomly chosen treatment group from hourly wages to piece rate pay while paying the control group hourly wages throughout. I have daily worker productivity data. Together, my data are from two ranches, 24 workers, and 7 days.

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series variation in firms that experienced a change in pay method. It then begs the question of what caused the firm's switches in pay method. If, for example, a trend or a change in general management style led to a change in compensation methods as well as an increase in productivity, fixed-effect estimation yields biased estimates as well.

A first pass of the data suggests that the productivity increase with a switch in pay method is around 23 and 36 percent at each ranch, respectively. Further exploration — allowing errors in the firm's set level of piece rates — suggests that the true productivity effect is closer to 23 percent. Variance among workers' productivity also increased. Quality of the thinning, however, did not change. These results are robust to different estimation methods and inclusion of a series of control variables. Since there was no turnover during the experiment, I have nothing to say about the selection effect of a piece rate contract. I did, however, conduct a questionnaire, responses from it suggest that a high ability worker prefers a piece rate to an hourly wage contract.

The closest paper is Shearer (2004) examining tree-planting in British Columbia, Canada. Shearer implemented an experiment where he randomized 9 workers into hourly wages or piece rates on each day, having in the end 120 person-day observations.

The main difference between Shearer (2004) and this study is the experiment design: I have a control group and a treatment group which is treated halfway through the experiment, while Shearer (2004) achieved the treatment by randomizing each one of all workers into piece rates everyday. Therefore, these two papers both have a difference-in-difference estimator, albeit using different ways to achieve the treatment. The strength of the Shearer (2004) approach is that his method maximized the possible number of treatments. The weakness of his approach is that a worker can hold up his effort during his hourly wage days so that on piece rate days he can work hard and earn a good pay. In this aspect, the way that I achieved the treatment is closer to real life: when one is assigned a contract, it is unlikely that he will be working under another contract the next day.

Besides its contribution to examining the incentive effect of a piece rate contract, this paper adds to a growing literature that uses field experiments to study a variety of personnel economics issues. Nagan et al. (2002) studied the effect of monitoring on employees' opportunistic behavior in telemarketing, Bandiera et al. (2005) examined the collusion effect of a relative performance evaluation contract in fruit-picking, Bandiera et al. (2006) investigated the effect of managers' incentive contracts on their favoritism in fruit-picking, and Fehr and Goette (2005) examined the impact of a greater piece rate on messengers' choice of working hours and efforts.[3]

This paper proceeds as follows. Section 2 describes the experiment, Section 3 examines the change in productivity after the switch into piece rate pay, and Section 4 provides some evidence of the selection effect of piece rate contracts. I conclude in section 5.

2. The Controlled Field Experiment

2.1 Experiment Design

The experiment was conducted in July 2006 at Yakima Valley Orchards (YVO), a sizable orchard operation in Central Washington State covering 800 acres of land, growing apples, cherries, and pears. The three most labor intensive jobs are harvesting (or picking), pruning, and thinning. Thinning is the process of removing small and imperfect apples from the tree half way through the growing season; it is much more time efficient to thin out the bad apples when the apples are growing than to sort through and remove the bad apples at harvest time. In addition, the remaining apples can receive better light. In 2005, YVO employed 53 permanent (or year-round) workers as well as approximately

[3] For use of field experiments in answering a broader set of questions, see List (2004) for a bibliography.

160 temporary workers who typically work three months a year, paying $2.1 million in wages for the jobs of harvesting, pruning, and thinning.

Piece rate contracts were known to work well for picking, whereas for thinning hourly wages were used. The owner was unsatisfied with workers' productivity in thinning and was interested in finding ways to improve his orchard's productivity in thinning. The owner's other concern was how to attract and retain the workers, who are being enticed to leave the agriculture jobs that on average pay $8 per hour, for better-paid industrial jobs in butchering, truck-driving, and retailing, for example.

A student of mine working as an intern at YVO was commissioned to provide solutions to the above problems. Piece rate contracts were recommended as a candidate for helping improve productivity in thinning. Having gained the owner's consent to running a field experiment to find out the incentive effect of a piece rate contract, my student ran the experiment on the site.

YVO is composed of approximately 65 blocks (of vastly varying sizes) divided into eight ranches with six managers hired to supervise front-line workers. To run an experiment on a block of a ranch, my student first must convince the ranch manager to participate. Managers were willing to participate in the experiment, since, in addition to salary, they were paid five percent of the net income of the individual ranch that they manage.[4] The other criterion is that the block of apple trees be uniform in the number of trees across rows and the thickness of apples on trees across trees, the rationale for which is that other changes before and after the switch in pay scheme is minimized. The tradeoff is that it was difficult to find a highly uniform block in the orchard.

[4] The six managers are also entitled to two percent of the whole firm's net income for the year.

The first experiment was conducted at Ranch 1 in a block of 23.49 acres of Granny Smith apple trees. There are 1000 trees per acre and the trees are planted in rows of approximately 180 trees per row in approximately 5.6 rows. Fourteen workers who were working at the ranch were put under the experiment.[5] At an average historical productivity of 65 trees per hour (around one third of a row per hour, that is, close to 7.5/3 = 2.5 rows per day), it was expected that the block would be finished in (23*5.6)/(2.5*14) = 3.68 days.[6]

Before the thinning of the block started, using a computer, we randomly assign seven of the fourteen workers to a control group and the other seven to a treatment (or test) group. On the first day, all of the workers worked under hourly wages, with an average hourly wage of $8.05 per hour. On day 2, the seven workers in the control group kept working under hourly wages, while the seven workers in the treatment group were switched to piece rate pay at a level set by the owner.[7] These 14 workers historically worked mainly under hourly wages and were kept in the dark about the experiment until the beginning of day 2 when half of the workers were switched into piece rate pay. Workers were told that the company was simply trying to find out how piece rate works.

Measures were taken to minimize other changes before and after the switch in pay scheme. One concern was the spill-over effect: control group workers will catch up with their piece rate fellow workers to avoid looking slow. A worker might also experience emotional fallout from knowing that a fellow worker is being paid differently,

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[5] These workers worked at the ranch before they started this thinning job. In the summer, workers usually first pick cherries, then start thinning apple trees and do other maintenance until pear and apple harvests begin.

[6] As will be shown in Section 3, the trees turned out to be much thinner and the ranch was finished in two days instead of the previously estimated 3.68 days. Piece rate was introduced on day 2 instead of the originally planned day 3.

[7] More details in Section 2.2 on how the piece rate was set.

introducing noises to estimates of the productivity effect of piece rates. The field researcher (my student) and the ranch manager thus decided to allocate the control group to one end of the block and the test group to the other end to minimize possible communication (so that workers from one group can neither see nor communicate with those in the other group about their pay methods).

Although the picked block was uniform across rows in the number of trees per row, one still needed to make sure that the thickness of a tree – the number of apples on a tree – remains the same before and after the switch in pay scheme. If not, the change in thickness needed to be measured. During the process of thinning, workers threw the imperfect apples onto the ground and the field researcher counted the apples on the ground to get an idea of the thickness of the trees thinned by a worker. It was costly to do this counting for every tree; the field researcher thus picked three spots in a row, between trees number 15 and 17, 45 and 47, and 75 and 77. At an average speed of one third of a row on day 1 and 0.6 row on day 2, the block was finished by the 14 workers in two days. At the end of each day, the manager picked one row for each worker and counted the apples that lay within an area of 87.12 square feet.[8] At the end of the experiment, the manager asked the workers the questions from a questionnaire.

The rows thinned by the control group had a mean of 47.52 apples on the ground under hourly wages and 44.90 apples under piece rates. The rows thinned by the test group had 86 apples on the ground under hourly wages and 51.86 apples under piece rate.

[8] Trees in this block were planted in rows. The rows were planted 13.2 feet apart from each other and the trees in each row were planted every 3.3 feet. Therefore, the apples were counted, for example, for trees 10 to 12, from an area of 3.3 * (12 – 10) * 13.2 = 87.12 sq ft.

It is apparent that apple trees at the starting end of the test group were much thicker than those at the starting end of the control group.

The highest temperature was 96 F on day 1 and 95 F on day 2. Workers started at 5:30 a.m. and ended at 1:30 p.m. on both days and took a break of 30 minutes from 12:00 p.m. to 12:30 p.m.

The second experiment was conducted at Ranch 2 in a block of 10 acres of gala apple trees. In each acre of the block, there were around eight rows of around 96 trees each. The manager switched all workers from hourly wages to piece rate pay halfway through the experiment, effectively a before-after approach. This time, the owner and the ranch (thus the block) manager forwent the use of a control group in light of the owner and his ranch 1 manager's in which they had to deal with the disgruntled control group workers who discovered that their fellow workers were paid piece rates.[9] Table 1B provides some summary statistics of this block at Ranch 2. First, this block is obviously much thicker compared with the block at Ranch 1; under hourly wages, an average worker at this block thinned 11 trees per hour while he thinned 65 at the block of Ranch 1. At the end of each day, the field researcher went down a finished row for each worker and counted apples on the ground between trees numbered 20-22, 50-52, and 70-72.[10]

In order to have an accurate count of apples on the ground for one worker's row, the owner and the manager decided to ask workers to work on every other row.[11] At the

[9] The farm made up with the control group workers after the experiment ended by paying the control group workers piece rate pay for their day 2 outputs.
[10] There are between 90 and 110 trees per row.
[11] At Ranch 2, the trees were planted in a straight trellis, which is a single tree-supporting wood pole extending straight up. To guide tree growth, wires were set up from pole to pole in the row, and the worker could not easily switch sides. With this system of planting, a worker must walk down and thin one side of the trees and then walk back and thin the other side of the trees. Down a row, apples could have come from either of two adjacent rows of trees, which were worked on by two different workers. At Ranch 1, however, trees were planted in a "V trellis, " for which type of planting workers were able to walk down one single

end of each day, the field researcher counted the apples on the ground and cleaned up the area so that the workers could have a clean area for the next day. An advantage of allocating workers this way is that before and after the switch, workers worked on adjacent and thus similar rows.[12] Indeed, the average number of apples on the ground before the switch on day 2, 163.98, is quite similar to that on day 3, 157.22.

The block at Ranch 2 proved to be non-uniform as well. At the end of day 3, all except two workers finished the even ones of rows 11-30 and began working on the even ones of rows 31-50. Sometime into day 4, they finished those rows and began working on the even ones of rows 51-70. This end of the ranch is much thinner compared with the beginning end. The data shows that the mean number of apples on the ground on day 4 (for rows that were worked on at the end of day 4) was 84.54, while it was 163.98 on day 2 and 157.22 on day 3.

Unfortunately, the researcher did not record the apples on the ground for those rows finished in the middle of day 4; what the manager counted were for the rows that the workers came to work on at the end of day 4 – even rows of rows 51-70. I used a linear interpolation — the average of day 3 thickness and day 4 thickness to calculate the thickness of tress finished during day 4, yielding a [(157.22 + 84.54)/2]/163.98 = 73.71 percent of that for day 2.

What is more, the manager did not anticipate the implication of a straight trellis on counting apples on the ground, and was unable to obtain the apples on the ground count for trees worked on at day 1. Therefore I needed to come up with a measure of the

row and thin both sides of the trees. Therefore, apples on the ground came from one worker's row and it was feasible to count the apples on the ground for a row thinned by a worker.

[12] Unfortunately, the manager did not anticipate the implication of a straight trellis on counting apples on the ground, and was not able to obtain the apple on ground count for trees worked on at day 1.

apples on the ground count for day 1 since the data was missing. I knew that the average tree thickness of odd ones of rows 11-30 was 1, even ones of rows 11-30 was 0.9587, even ones of rows 31-50 was 0.7371, and even ones of rows 51-70 was 0.5155. Assuming the thickness of trees declines linearly, I estimated a thickness of trees at rows 1-10 of 1.176525.[13] The 10 workers finished the ranch in 5 days.[14]

2.2 Setting the Level of Piece Rate

The owner believes that he should pay $10 an hour to be competitive (the participation constraint in a Principal-agent model). Let y_{hr} denote the number of trees thinned per hour under hourly wages and y_{pr} under piece rate. For the 14 workers enlisted to work at Ranch 1, the average hourly wage rate was $8.05. For the owner to make more money under a piece rate than an hourly wage, he should expect to see a productivity increase greater than 10/8.05 = 24.2 percent; at such an observed productivity of y_{pr} number of trees per hour, the piece rate should be at a level of $\frac{\$10}{y_{pr}}$, attractive enough to keep the worker from being lured away by other industries.[15] If the expected productivity increase is less than 24.2 percent and the owner aims for a greater

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[13] Assume that odd and even rows decline at the same rate. For even rows, every twenty rows declined by 1 - 0.7371 = 0.2629, which means each row declined at a rate of 0.013145. For odd rows of rows 11-30, denote the thickness of odd rows of rows 21 to 30 as *x*, then the thickness of odd rows of rows 11 to 20 is then (*x* + 0.12145). We then have (*x* + *x* + 0.13145)/2 = 1, that is, *x* = 0.934275, thickness for odd rows of rows 21-30 is 0.934275. Thickness for odd rows of rows 11-20 is thus 0.934275 + 0.13145 = 1.065725, and thickness for odd rows of rows 1-10 is thus 1.065725 + 0.13145 = 1.197175. Similarly, denote thickness of even rows 21 to 30 as *x*, then (*x* + *x* + 0.13145)/2 = 0.9587, that is, *x* = 0.892975. Even rows of rows 11-20 thus have thickness of 0.892975 + 0.13145 = 1.024425, and even rows of rows 1-10 have thickness of 1.024425 + 0.13145 = 1.155875. In the end, the rows of 1-10 have a thickness of (1.197175 + 1.155875)/2 = 1.176525.

[14] On day 5 after the workers finished the odd rows of rows 51-70 (in the morning), the manager counted the apples on the ground for those trees, and workers finished the remaining rows of the field -- odd rows 31-70 and remaining few rows.

[15] It is worth noting that in this setting, either a pure piece rate or a pure hourly wage is used; there are not compensation packages that include both a base hourly wage and a piece rate. The reason could be that there are fixed costs in setting up either of the two.

profit under piece rates, the owner should expect to pay less than \$10 an hour, at a level of $\frac{y_{pr}}{y_{hr}} * \$8.05$, where the hourly earnings will be less than \$10 per hour:

$$\frac{y_{pr}}{y_{hr}} * \$8.05 \leq 1.242 * \$8.05 = \$10.$$

At the block of Ranch 1, before the experiment started, it was believed by the ranch manager that a motivated worker of average ability could thin around 50 trees per hour (the expected y_{pr}), and the observed average worker output under hourly wages was 37.5 trees per hour. Since 50/37.5 = 1.33, the piece rate was set at $\frac{\$10}{y_{pr}} = \frac{\$10}{50} = \$0.2$ per tree.

At the block of Ranch 2, the current average hourly wage level was \$7.75. For the owner to make more money under a piece rate than an hourly wage, he should expect to see a productivity increase of greater than 10/7.75 - 1 = 29.03 percent; at the observed productivity y_{pr} number of trees per hour, the piece rate should be at a level of $\frac{\$10}{y_{pr}}$. During the first two days when hourly wage was used, the average hourly number of thinned trees was 11.01. If the piece rate productivity could indeed reach 11.01 * 1.2903 = 14.21, then the piece rate should be set at \$10/14.21 = \$0.70.

The manager for Ranch 2, who was previously a very fast worker, said he could thin 20 trees an hour; and he wanted to set the piece rate at $\frac{\$10}{20}$ = \$0.50.[16] At the set rate

[16] Since the ranch manager is known to be very fast, much faster than an average motivated worker, my student was concerned that the piece rate was set too low. The manager insisted, claiming that it was better setting it too low and then adjusting it upward than setting it too high and meeting workers' resistance in case of needing to adjust it downward.

of \$0.50 per tree, to earn an hourly income of \$10, an average worker needed to raise his productivity by 20/11.01 - 1= 81.65 percent, which appeared exceedingly high.

One can see that, in using piece rates as the compensation method, the manager needs to adjust the field level piece rates to the expected productivity of an average motivated worker at that field, which requires an estimation that is based on historical data on workers' productivity and an accurate assessment of conditions in that specific field or block. Also worth noting is the fact that although a rate is set for each distinct field, that rate applies to all workers enlisted to work on that field.[17]

3. Results on Productivity Effect of Piece Rates

3.1 Graph Analysis

The unit of observation is person-day; Ranch 1 has 14 * 2 = 28 and Ranch 2 has 10* 4 = 40 observations. The variable of interest is a person's daily effort; since it is unobservable (to a manager, an owner, or an econometrician, and that is why we call it an agency problem), it is measured using a worker's daily productivity -- the number of trees thinned per hour. Figure 1A shows the 14 workers' number of trees thinned per hour (workers 1 to 7 belong to the control group and worker 8 to 14 the treatment group) at Ranch 1. One curve depicts workers' productivity before the switch and the other after the switch.

[17] This eliminates a potential way to extract rents from a high-ability worker; the firm could have given a high-ability worker a low piece rate. As Kanemoto and MacLeod (1993) argued, an active market for this kind of worker prevents a firm from "ratcheting up the standard" or "lowering down the piece rate." Of course, the firm has other ways to extract rents from a high-ability worker. For example, it could assign fast workers to more difficult fields. As will be shown in Section 3, the firm did not do this; a field had workers of a wide spectrum of ability. The reason that the firm did not act this way could be for the same reason; had the firm done it, the workers could leave this firm or, if they are stuck with this firm this season or this year, they would not come back the next season or year (and they could spread the word out to other potential workers.)

The control group started at the west end of the ranch, which is the thinner end, and moved eastward, and the treatment group started at the east end, which is the thicker end, and moved westward (to avoid communication of the two groups). As discussed in Section 2, in measuring the true productivity, I needed to adjust the number of trees thinned by the thickness of apples in a tree.

Two methods can be used for the adjustment. The field researcher recorded the number of apples left on the ground at three points of a row that a worker finished. I thus could use the number of apples on the ground for each worker on a day to adjust for a worker's daily productivity. Method 2 was to use the average number of apples on the ground for each group (the control and test group) on a day to adjust for a group member's daily productivity. Method 1's strength is that it accurately measures the thickness of the trees in a row that a worker worked. Its weakness is that it has only three data points to estimate the thickness of apples of a row. On the contrary, method 2's strength is that it has (3 * number of workers in a field) observations to estimate a field's thickness of apples, and its weakness is that it uses the field's thickness of apples to measure an individual row's thickness.[18] Whenever possible, I present results using both methods. In most cases, results are robust to either method.

There was great variability in the number of apples on the ground across rows for a group, possible for two reasons. First, the rows within that group were heterogeneous. Second, rows were quite homogeneous within that group, but there was a lot of randomness in how workers threw apples on the ground within an area of 87.12 square feet for each spot. If the variation mainly came from the trees across the rows, method 1

[18] If the thickness of trees follows a trend, using group average thickness to measure an individual worker's tree thickness may introduce noise.

is preferable since it better captures the true productivity of an individual worker. If the variation mainly comes from the second, method 2 is preferable since it can effectively reduce this randomness.

Figure 1A uses the group average apple counts on the ground as the adjustor. Two regularities emerge. First, productivity for the control and the test group before the switch (under the hourly wages) is very close at a level of 84 trees (close to half a row) per hour, which reflects the random nature in selecting workers into the groups. Second, workers in the control group did not witness much change in the number of trees thinned per hour before and after the switch in pay, yet the workers in the test group witnessed a significant increase in the number of trees thinned per hour.

Noteworthy in Figure 1A is also the substantial heterogeneity in workers' productivity when they were all paid hourly wages.[19] Probably reflecting this, there was substantial heterogeneity in workers' level of hourly wages.

Figure 1B plots the worker-level number of trees thinned per hour at Ranch 2, adjusted for the thickness of trees using the group average number of apples on the ground. The upper curve represents average (over day 3 and 4) productivity after the switch, and the lower curve represents the average (over day 1 and 2) productivity before the switch. Productivity after the switch appears significantly higher than that before the switch. Figure A1 and A2 (in Appendix) are identical to Figures 1A and 1B except that the adjustor is the individual row count of apples on the ground. Figure A3 in the Appendix plots day 2 and day 3 productivity instead of the averages. In all these figures the same pattern is observed.

[19] If it is true that, under hourly wages, workers choose to work at a level that is most comfortable for them, the productivity then reflects the heterogeneity in workers' degree of comfort with working, which is probably highly correlated with workers ability.

<Insert Figure 1A and 1B about here>

3.2 Table Analysis

Table 1C provides the mean number of trees thinned per hour at the block of Ranch 1. The first three columns use the raw data: an average worker in the control group thinned 84 trees per hour before the switch and 101 after; meanwhile, the treatment group thinned 46.4 trees per hour before and 117 trees after the switch. Based on these raw data, the increase in productivity for the treatment group is 152 percent and that for the control group 20 percent, resulting in a difference-in-difference estimate of 133 percent for the change in productivity due to switching to piece rates from hourly wages.

As I discussed in Section 2, this raw number overestimates the true magnitude. Columns 4 – 6 display results using the individual worker's row thickness of apples as the adjustor: on day 1, an average worker in the control and treatment group thinned a very similar number of trees per hour. On day 2, the hourly number of trees thinned for the control group increased by 11 percent, and that for treatment group increased by 50 percent, resulting in a difference-in-difference estimate of the productivity effect of piece rate versus hourly wages of 39 percent. The last three columns show the results using the group average thickness of apples as the adjustor. The control group saw an increase in productivity of 13 percent and the treatment group 52 percent, thus a 39 percent increase for the difference-in-difference estimator.

<Insert Table 1C about here>

Table 1D shows the experiment results at the block of Ranch 2. Columns 1-3 use raw data. For the two days before the switch, an average worker's hourly number of trees thinned was 11.01, and an average worker's productivity after the switch (on day 3 and 4) was 17.85, a 62.10 percent increase. As discussed in Section 2.1, the trees were not uniform across the orchard. Columns 4-9 use the linear interpolation method to get a measure of apples on the ground for day 1. Using the individual row count of apples on the ground as the adjustor, the productivity increase was 23.72 percent; using the group count of apples on ground, the productivity increase was 23.17 percent.

The average productivity masks the difference in productivity between day 3 and 4. Day 3 productivity was 16.12 trees per hour while that on day 4 was 13.71. Whether this reflects a Hawthorne effect is examined in the next section.[20]

<Insert Table 1D about here>

3.3 Regression Analyses

3.3.1 Productivity

Since data are generated by randomly picking workers into control and treatment group, simple statistics – a difference-in-difference estimator in a Table as in Section 3.2 pretty much captures the information on the productivity effect of the piece rates; as shown in column (7) of Table 1C, the day 1 average productivity for the control and the treatment group is very close, reflecting our randomization experiment design. Still, the treatment may correlate with workers' ability in unknown ways. To teeth out the effect of unobserved ability and other observable characteristics from that of the change in incentive scheme at Ranch 1, I use a regression analysis and estimate an equation with the following specification:

$$Y_{it} = \beta I_{it} + \alpha_t + \alpha_i + \beta_x X_{it} + u_{it}, \qquad (1)$$

[20] The Hawthorne Effect, named after the Hawthorne Western Electric Plant in Illinois, alleges that any change will bring about a short-term productivity gain.

where Y_{it} is the hourly number of trees thinned by worker *i* at date *t* adjusted for the thickness of apples, I_{it} is an indicator variable, which takes the value of 1 when worker *i* is paid by piece rate at date *t*, α_t is date fixed effect, α_i is worker fixed effect when applicable, X_{it} is the vector of worker characteristics, and u_{it} is the error term assumed to be a random white noise. I am interested in knowing how a change from hourly wages to piece rates affects productivity; the coefficient of interest is β. The change in productivity from day 1 to 2 may be attributed to weather change or the change in workers' proficiency in working at this ranch; I therefore include α_t to capture these factors. The coefficient β in equation (1) thus is a difference-in-difference estimator.

Table 2A provides the regression results. Columns 1 to 4 adjust the number of trees thinned using group average number of apples on the ground and columns 5 to 6 using individual row count. Column 1 estimates Equation (1) without including the date 2 dummy. The coefficient suggests the change in productivity due to the change in compensation scheme is 48 percent.[21] Column 2 estimates Equation (1) with both the indicator variable and the date 2 dummy, yielding a difference-in-difference estimator of 36 percent. Through a questionnaire, I was able to collect information on workers' characteristics, such as age, marital status, number of children, and months having worked at Yakima Valley Orchards; column 3 provides results when these additional variables were incorporated. The productivity increase in this case was 40.50 percent, and the coefficients on the demographic variables (age, marital status, number of children) were insignificant. The coefficient on the experience variable was significant, however,

[21] The 48 percent figure is derived this way: *ln*(productivity after the switch) – *ln*(productivity before the switch) = *ln*(1 + growth rate) = 0.39 ➔ growth rate = 48 percent.

of the value of 0.0016, meaning one more year of experience at YVO raised productivity by 0.0016*12 = 1.92 percent. When I included the worker fixed effects in column 4, the difference-in-difference estimator remained at 36 percent, confirming that the assignment of workers into a control and treatment group was indeed random. Columns 5 and 6 are identical to columns 2 and 3 except that the adjustor is individual row count of apples on the ground. The coefficient on the variable of interest is of slightly greater magnitude but the standard deviation is also greater. Overall, results in Table 2A suggest that the change in productivity due to a switch from hourly wages to piece rate pay is on the order of 36 percent.

<Insert Table 2A about here>

At Ranch 2, all workers were switched to piece rates halfway during the experiment. The equation to estimate is

$$Y_{it} = \beta I_{it} + \alpha_i + \beta_x X_{it} + u_{it} . \qquad (2)$$

Compared with equation (1), equation (2) has no date fixed effect since the change in compensation scheme coincides with date changes.[22] The coefficient of interest, β, is thus a before-after estimator.

Similar to the argument in the previous paragraph, since this is an experiment and every worker is treated, the indicator variable, I, does not correlate with the unobserved worker ability. Including it, however, still can help control for the heterogeneity in workers' productivity, and thus will affect standard error of the estimators.

Table 2B provides regression results with group average count of apples on the ground as the adjustor and the thickness of apples for rows of missing data estimated

[22] Recall that at the block of Ranch 1, there was a control group so changes in compensation scheme did not coincide with date changes for all workers.

using the linear interpolation. Odd columns use OLS while even ones include work fixed effects. Columns 1-2 are of the simplest specification, with the indicator variable being the only explanatory variable. OLS and worker fixed effect yield very similar results, a 23.7 percent increase in productivity, and the standard error of β with worker fixed effects is slightly lower than without. Columns 3-4 add a control for day 1 when the trees finished during the day did not include apples on the ground counted. Now the coefficient of interest decreases to 17.35 percent, which is not surprising given that productivity of day 1 after the linear interpolation adjustment is lower than that of day 2. This specification effectively compares productivity of day 2 with that after the switch. Columns 5-6 add to columns 3-4 still another control variable – a dummy variable for day 4 to capture the fact that the thickness of trees thinned during day 4 was estimated using a linear interpolation. The coefficient of interest changes into 23 percent, which is not surprising given that productivity of day 4 is lower than that of day 3. This specification effectively compares productivity on day 2 with that on day 3. Columns 5-6 provide the highest R-squared score. The overall message from Table 2B is that incentives, measured by hourly trees thinned, increased by 23 percent after the payment method switched from hourly to piece rate pay, a level that is lower than at Ranch 1, yet very close to those in Lazear (2002) and Shearer (2004).

At first glance, the negative coefficient on day 4 suggests the existence of a Hawthorne Effect. Before drawing this conclusion, one needs to consider two things. First, the coefficient on day 4 is statistically insignificant. Second, the workers finished the whole apple block in five days. Although worker-level productivity data were collected only for the first 4 days, I do have the summary productivity data on day 5 – an average of 17.50 trees per hour. With the average being 15.34 on day 3 and 13.71 on day 4, the elevated productivity on day 5 does not support the existence of a Hawthorne Effect.

<Insert Table 2B about here>

3.3.2 Discussions of Results on Productivity

Our exercise in Table 2A for the block at Ranch 1 might overestimate the effect of a real-life piece rate. The rate, $0.2 per tree, was set based on an expected piece rate productivity of 50 trees per hour; in hindsight, the piece rate productivity (after adjustment for thickness of trees) was 128 trees per hour.[23] Had the piece rate been set at a reasonable level, the productivity effect would have been lower. On the other hand, our estimate may have underestimated the effect of piece rate: Around 8:30 a.m. of day 2 (workers worked from 5:30 a.m. to 1:30 p.m.), as the workers from two opposing ends of the block converged to the middle of the block, workers in the control group learned that their fellow workers in the other half of the ranch were being paid piece rate. They expressed their concern and the management decided to say that the firm is running an experiment and that they would all be paid piece rates the next day.[24] It thus could be that workers in the control group wanted to demonstrate that they are no less good and tried to catch up, which would make our difference-in-difference estimator underestimate the true effect of the switch in pay scheme. But given that the management made it clear that this is only an experiment, the magnitude of underestimation is probably small. If one believes that the effect of an abnormally high level of piece rate is greater than the

[23] The rate was set too high; at the set level, an average worker would have earned $23.35 per hour, much higher than the competitive level -- $10 per hour. More discussion on this in Section 3.6.
[24] It was found later on day 2 that the block was nearly done; there was thus no third day for this experiment.

spillover effect, it is safe to say that based on data from Ranch 1, the upper limit of the productivity effect of a piece rate contract is 36 percent.

For the block at Ranch 2, the starting end is thicker than the remaining block; I used a linear interpolation method to estimate the thickness of apples. It is informative to see the sensitivity of the results to different assumptions of the thickness of trees in these thick rows.

Table 3 provides the results of the sensitivity checks. Row 1 transcribes the baseline results where the explanatory variables include the piece rate dummy, a control for day 1, and a control for day 4. Columns 1 and 2 provide results using OLS and worker fixed effects, respectively. The two estimation methods yield very similar results. In column 3 of Table 3, I provide the percentage change of productivity. Assuming that the thick rows are as thick as the rows thinned on day 2, the odd rows of rows 11 – 30, row 2 shows that the coefficient of interest is 0.26, meaning a 30.33 percentage increase in productivity after the switch in pay method, greater than the baseline result of 23.10 percent. Similar exercises are shown in rows 3 and 4 when I assume that the thick rows are 1.1 and 1.2 percent thicker, respectively, than rows thinned on day 2.[25] The percentage changes turn into 26.11 and 22.21 percent, respectively. The estimate is sensitive to the assumption of thickness of rows on day 1 in a predictable way: the thicker the rows thinned on day 1 are assumed to be, the lower the estimated productivity increase.[26]

[25] Recall that according to the linear interpolation, the thickness of trees thinned on day 1 is 1.176525 times that on day 2.

[26] Another force for a possible upward bias is the change in weather. The highest temperature was 98 F on day 1 and 94 F on day 2. It dropped to 84 F on day 3 and 92 F on day 4. One can not rule out this possibility, yet we should also realize that workers started their work at 6am and end at either 12:00 or 3:00 p.m.

During day 1 when workers worked on the thick rows, workers finished the bottoms of trees and then walked back and worked on the top of trees. Trees were on average 11 feet tall and a worker could on average reach 7.5 feet above ground without a ladder. Therefore when a tree's bottom was finished and the top unfinished, I calculate it as 7.5/11 = 0.68 of a tree finished. The fifth row provides the results when I assume that a bottom is equivalent to 6.5/11 = 0.59. The result is quite similar to the baseline results.

At the third (natural) day of the experiment, workers were told that they would be paid piece rates at the rate of $0.50 per tree when they start on even (the piece rate) rows; they had to finish the odd rows that they had not finished at the end of day 2 and be paid hourly wages before they would start the piece rate rows and get paid by pieces. Therefore, there were different times that workers worked under piece rate pay. At 7:00 a.m. it started to rain and the workers stopped working for the day. This first hour of natural day 3 and the hours of natural day 4 that workers used to finish the odd (hourly wage) rows can be thought of as day 2.5 of the experiment. In the previous analysis, day 2.5 productivity was merged into day 3 productivity, which was treated as productivity under piece rates. The justification is that during day 2.5, a worker's opportunity cost was the piece rate pay. Here I do a robustness check by separating the day 2.5 (before workers started the piece rate rows) productivity from day 3 (after they worked on piece rate rows) productivity. The third row from the bottom of Table 3 shows that the estimated productivity effect becomes 33.04 percent. Since day 2.5 covers early hours of natural day 3 and 4 and assume that workers wear out as the day progresses, I add a control variable for day 2.5. The second row from the bottom of Table 3 shows that the estimated productivity effect of piece rates is 19.78 percent. If the assumption that workers wear out as the day progresses is correct, this estimator of 19.78 percent underestimates the true productivity effect. For the same reason, 33.04 percent overestimates the true productivity since the merged (day 3 of the experiment) piece rate productivity contains two mornings.

The last row of Table 3 provide the estimated coefficient of interest for Ranch 2 when I include demographic variables – age, marital status, number of children – and work experience. Demographic variables have little explanatory power. Work experience is positively related to productivity, but barely statistically significant. The coefficient of interest is statistically significant and it is at a level very close to the baseline estimate of 23 percent. I take away from the exercises in Table 3 that the effect of a switch from hourly wages to piece rates is on the order of 23 percent.

<Insert Table 3 about here>

3.4 Greater Variance in Productivity after the Switch?

Theories tell us that under hourly wages, both high and low ability workers, beyond meeting the required minimum effort level will choose to exert their efforts at a level that is most comfortable for them. According to Figure 1A, there was some heterogeneity in the hourly wage workers' productivity. Under piece rate pay, however, both will exert effort at a level that equates the marginal benefit to the marginal cost (Lazear 1986), which means that an able worker will work at an effort level that is greater than a less able one since the former has a lower cost of exerting effort. It is expected that the variance of output under piece rate is greater than that under hourly wages.

Table 4A provides the level and standard deviation of hourly productivity level for Ranch 1. I find that, when adjusted using the group average count of apples on ground, the control group's standard deviation increases, as does that of the test group, yet by a smaller percentage. [27] At first glance, the result appears to contradict the theoretical prediction. It is known, however, that the fast workers in the control group, by moving faster, reached the middle of the block earlier and got to know that their peer group was paid piece rate (and thus possibly worked harder to demonstrate their eligibility), while other workers (the slower ones) in the control group got to know that much later. This may help explain the greater variance in the control group's performance.

<insert table 4A about here>

Looking at Table 4B, which is for Ranch 2, there appears a pattern that is consistent with the theoretical prediction: when adjusted using the group average count of apples on the ground, workers' productivity had a greater standard deviation after the switch into piece rate pay.[28]

<insert table 4B about here>

If the individual row count of apples on the ground is used, the pattern is the same as when the group average count is used, except that the level of standard deviation is greater, as shown in Table A1 and A2 in Appendix.

3.5 Results on Quality

Did the workers increase the speed at the cost of quality? Managers controlled the quality by reviewing the trees that were thinned. When the worker did it well, the manager praised him; if the manager found repeatedly that the quality was poor he would ask the worker to go back to redo the tree; a worker is not paid for the tree until it is

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[27] Yet, the growth in the standard deviation is smaller compared to the growth in the mean, which Lazear (2000) also found.

[28] The growth in the standard deviation is greater compared to the growth in the mean.

properly redone. If the workmanship was not bad enough for the manager to ask a worker to go back and redo his work, the manager would remind the worker to improve his quality.

Quality is judged on a 1-5 scale: the score is 1 if 99 percent or more of spurs are thinned well, 2 for 95 percent or more, 3 for 90 percent or more, 4 for 85 percent or more, and 5 for less than 85 percent. The average quality level for Ranch 1 is 1.09, meaning that an average worker thinned 99 percent or more of the spurs for most of the trees that he did and thinned 95 percent or more of the spurs for a few of the trees that he did. The average quality level for Ranch 2 is 1.37.

At Ranch 1, the control group's quality level decreased from 1 to 1.14 and the test group from 1.07 to 1.14. At Ranch 2, the average quality level decreased from 1.28 to 1.45.

Table 5A provides regression results for Ranch 1, where the specifications are identical to those in columns 2 and 3 of Table 2A except that the dependent variable is the quality. In either OLS or worker fixed effect regression, quality does not change after the switch in pay method.

<insert table 5A about here>

Table 5B provides regression results for Ranch 2 where the specifications are identical to those in Table 2B except that the dependent variable is quality. The emerging pattern is that quality dropped with the switch into piece rate pay, but *t*-value is at best 1.58. Day 4 appears to have a higher quality level compared with day 3, and day 1 seems to have a higher quality level compared with day 2.

Combining the results of both Ranch 1 and Ranch 2, the message appears to be that while productivity increased with the replacement of hourly wages by piece rates, in this experiment, quality barely decreased. One plausible explanation is that the management made it clear that the worker was not paid for a tree that was poorly done. The second is that the manager kept an active check on the quality by providing workers timely feedback.

<insert table 5B about here>

3.6 Difficulty in Setting the Right Level of Piece Rate

Section 3.3 established that workers' productivity increased by 36 percent with the replacement of hourly wages by piece rate at Ranch 1.[29] It is illuminating to evaluate whether the piece rate was set at a fair level by examining whether both the owner and the workers are made better off under piece rates.

The employer's welfare gain is reflected by reduced wage bills. On day 1 when all workers were paid hourly wages, Ranch 1 was paying on average $8.05 per hour. At an average productivity of 65.24 (with a very wide variance – 31.2 to 99 trees per hour), an acre of Ranch 1 (1,000 trees) costs (1000/65.24)*8.05 = $123.39.

Unfortunately, the pre-set piece rate was not adjusted and was kept at ($10 per hour/50 trees per hour) = $0.20 per tree, an acre of Ranch 1 then demanded a wage bill of $0.20*1000$ = $200. On the other hand, workers were reaping a huge payoff: at $0.20 per tree and with a productivity increase of 36 percent, an average worker thinned 65.24 *

[29] Without building a full structural model, my analysis is short of a full welfare evaluation. Total surplus then increased by (1.36% * old productivity – increased costs of effort – risk cost – measurement costs). It is informative to examine how the surplus under piece rate is divided between the farm owner and the workers. Since the payment is entirely piece rate, the division of the surplus hinges on its level.

1.36 = 88.73 trees per hour, resulting in an hourly earning of $0.20 * 88.73 = $17.75, which is way above the $10 target that the owner thought competitive.[30]

What exacerbated the problem of setting the right level of piece rate was the non-uniformity of trees. At Ranch 1, even if the rate was set $0.1152 per tree (see footnote 30), it would not be right, since, ex post, it was found that the rows the treatment workers thinned on day 2 are 77.68 percent as thin as those on day 1; that is, workers were able to thin 1/0.7768= 1.29 times faster than they did on day 1. So, even at a rate of 0.1152, the hourly earnings would have been 65.24 * 1.36 * 1.29 * 0.1152 = $13.19. If, instead, the owner knew perfectly that the blocks on day 2 were 77.68 percent thinner than those on day 1, he should have set the piece rate at a level of 10/(65.24*1.33*1.29) = $0.0893 per tree. That way, the total cost bill for an acre would be 1000*0.0893 = $89.3, and for workers, the hourly earning would be (65.24*1.36*1.29)*0.0893 = $10.23.[31] In all, the actual $0.20 was gravely over the optimal level.

In Ranch 2, under hourly wages, the hourly productivity was 11.01 trees per hour. At an average of $7.75 per hour, the wage bill for an acre of Ranch 1 (805 trees) was 805/11.01 * 7.75= $566.6 per acre.

At a set piece rate pay of $.50 per tree, the wage bill was 805 * 0.50 = $402.5 per acre, a 29 percent decrease in cost per acre. Meanwhile, with a productivity increase of

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[30] The average productivity of 65.24 was much greater than the 37.5 figure used to obtain the piece rate. The piece rate should have been set, for example, at a level around $10/(65.24*1.33) = $0.1152 per tree; recall that 1.33 is the expected productivity increase used by the owners to calculate the piece rate, as detailed in Section 2.2. Had it been set at $0.1152 per tree, an acre of land would have cost 1000 * 0.1152 = $115.2, 6.6 percent lower than the wage bill under hourly wages; that is, the farm owner shared part of the surplus. Meanwhile, an average worker's hourly earning would have been 65.24 * 1.36 * 0.1153 = $10.23, quite close to the targeted $10 earning for an average worker, and a 10.23/8.05 - 1= 27.08 percent increase over his hourly wage rate.

[31] Had the piece rate been set at 0.0893 instead of actual 0.20, it would have been a 55.35 percent decrease from 0.20. Haley (2003) showed that the lower bound of the effort elasticity to piece rate is 0.413, which means that the effort, and the productivity at the right piece rate level (0.0893) would be 1.36 * [1 - (0.413 * 55.35%)] = 1.05 times that before the switch. Therefore, my results imply a smaller elasticity compared with that obtained by Paarsch and Shearer (1999) and Haley (2003).

23 percent, an average worker under piece rate earned 11.01 * 1.23 * 0.50 = $6.77 per hour, 12.65 percent lower than the original hourly rate, and 32.3 percent lower than a competitive $10/hour; it appears that the piece rate level was set too low.

As it turned out, the piece rate level was in fact set slightly too high. It was found that the rows on day 3 and 4 were 67.73 percent as thin as those on day 1 and 2;[32] that is, under piece rates, workers were able to thin 1/0.6773 = 1.4764 times faster than they did under hourly wages. So, even at the rate of 0.50, the hourly earnings would have been 11.01 * 1.23 * 1.4764 * 0.5 = $9.9969, precisely the competitive level; the percent increase in hourly earnings is 9.9969/7.75 = 28.99, yet the productivity increase was only 23 percent, which does not justify a 28.99 percent increase in hourly earnings; the rate was in fact set too high. It should have been set at the level: (7.75*1.23) / (11.01*1.23*1.47) = 0.4789. But overall, it was quite close; much closer to the optimal one than what was achieved at Ranch 1.

The above analysis showed the intricacy of setting the right level of piece rate for every field[33]: the contract designer needs information on an average worker's productivity and an accurate measure of the difficulty of the job at that field.[34] Under an hourly wage, although there is a need to assess the difficulty of the job, there is no need to do it across fields. Piece rate pay is more attractive when these measurement costs are low.[35] At YVO, managers got a fairly accurate estimate of the difficulty of the job by

[32] The 67.73 percent is reached through [(0.9587+0.7371+0.5155)/3]/[(1.176525+1)/2].

[33] My experiments confirm what Paarsch and Shearer (2004) found: there are errors in setting the level of piece rates. The fit of their model was greatly improved after allowing for the errors made by the management in setting the right level of piece rates.

[34] In addition, he has to measure the quantity of goods produced or services provided.

[35] In this sense, this paper relates to Leffler et al. (1991), which highlighted the effect of pre-sale measurement costs in timber-harvesting on the seller's choice of a fixed-price versus a piece rate contract.

sampling and thinning a tract of the field.[36] After these two experiments, YVO tried to implement piece rates as much as possible.

4. Results on Selection Effect of Piece Rate Contracts

One strength of our experiment is that it is free of attrition; the experiment was short and there was no turnover. It can also be thought of as a weakness; I have no variation in turnover to say anything about the selection effect of a piece rate contract.[37] I did, however, run a questionnaire where workers were asked whether they prefer piece rates or hourly wages. I thus could examine the question of whether high ability workers prefer piece rate pay, providing indirect evidence that high ability workers would be attracted to piece rate firms and low to hourly wage firms.

I measure ability using the worker fixed effects estimated from equation 1 for Ranch 1 and equation 2 for Ranch 2. I then regress the preference variable on the estimated worker fixed effect. The preference variable is a dummy variable that takes a value of 1 if the worker prefers piece rate, 0.5 if he is indifferent, and 0 if he prefers hourly wage. The mean of the preference variable is 0.62 for Ranch 1 and 0.80 for Ranch 2, which could reflect the fact that workers at Ranch 2 historically worked under piece rates while those at Ranch 1 worked under hourly wages.[38]

Figure 3A shows the scatter plot of the preference and ability variable for Ranch 1 and Figure 3B for Ranch 2. I have a very limited number of observations: 14 for Ranch 1

[36] Resulting from an error in estimating the condition of the field, this possible error in setting piece rates calls for a relative performance evaluation. That way, workers are shielded from the risk resulting from the noise in the piece rates. Unfortunately, relative performance evaluation invites collusion of workers, which was studied by Bandiera et al. (2005).
[37] In Lazear (2000), it was found that the implementation of a piece rate contract increased productivity by 44 percent, half of which is attributed to incentive effect, half selection effect.
[38] At YVO, ranch managers made the decision on the pay scheme. Some ranch managers used piece rates more often than others.

and 10 for ranch 2. It appears in Figure 3A that there is a noisy, but positive relation between these two variables; the positive relation seems stronger in Ranch 2.

<Insert Figure 3A, 3B about here>

Table 6 provides the regression results of the below equation:

$$preference\_piece\_rate_i = \beta * ability_i + \varepsilon_i . \qquad (3)$$

Column 1 of Table 6 is for Ranch 1 and column 2 for Ranch 2. The coefficient on ability is positive for Ranch 1, albeit not reaching statistical significance. The coefficient on ability is positive and statistically significant for Ranch 2. The magnitude of 1.93 suggests that for a standard deviation increase in ability, 0.14, the preference of piece rate increases by 1.93 * 0.14 = 27 percent.

<Insert table 6 here>

5. Conclusion

I conducted two small field experiments. In the first experiment, I randomly assigned half of the workers to a control group and half to a treatment group. Workers in the control group were paid an hourly wage throughout, while workers in the treatment group were initially paid an hourly wage but were later paid piece rate. In the second experiment, I switched all workers from an hourly wage to piece rate halfway through the experiment. The difference-in-difference estimator from a sample of 28 observations suggests a productivity increase of 36 percent, which is probably over-estimated since the piece rate was set overly high. The before-after analysis of 40 observations suggests an increase in productivity of 23 percent. Results from the questionnaire suggest that high ability workers prefer piece rate over hourly wage contracts.

This paper contributes to the literature on the productivity effect of piece rate contracts in achieving a randomized variation through a field experiment design. Of course, the concomitant weakness of an experimental study is the potentially limited applicability of the experiment results; the results may be specific to its particular environment. It is therefore advisable that the result of this study be taken in the context of other studies using other idiosyncratic environments. Among the studies that examined the productivity effect of piece rate contracts, Lazear (2000) used a natural experiment in a windshield-installing setting, Shearer (2004) used a controlled field experiment again in tree-planting, and this study ran a controlled field experiment of a different design in a tree-thinning setting. Across these studies utilizing field experiments, it appears that there is converging evidence of an approximately 22 percent productivity increase attributable to piece rate contracts.

This experiment also highlights the costs involved in implementing piece rates. A large literature exists on multi-tasking and the weakness of piece rate contracts in that they encourage dysfunctional responses (see Prendergast, 1999 for references). This is, however, not a big concern in this tree-thinning setting. The increase in productivity did not come at the cost of quality, which remained fairly high throughout. Highlighted in this study are the measurement costs: costs involved in measuring an average worker's productivity in a field in order to set up the right level of piece rate for that field. Still, these measurement costs are most likely small compared to the more than 20 percent incentive effect.

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Figure 1A: Worker-level Hourly Number of Trees Thinned at Ranch 1, Adjusted for Tree Thickness of Apples using Group Average Number of Apples on Ground

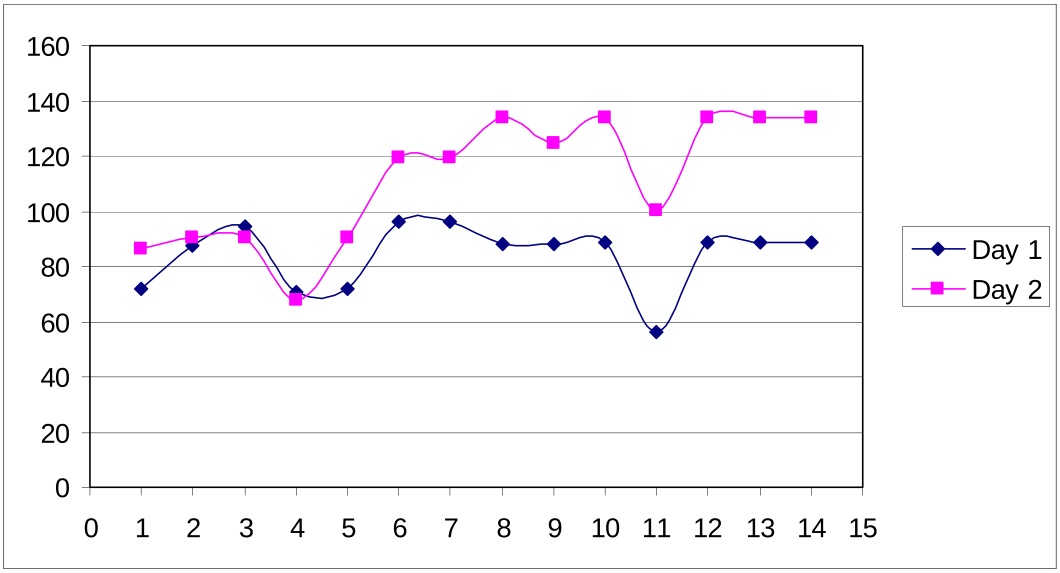


Figure 1B: Worker-level Hourly Number of Trees Thinned at Ranch 2, Adjusted for Tree Thickness of Apples using Group Average Number of Apples on Ground

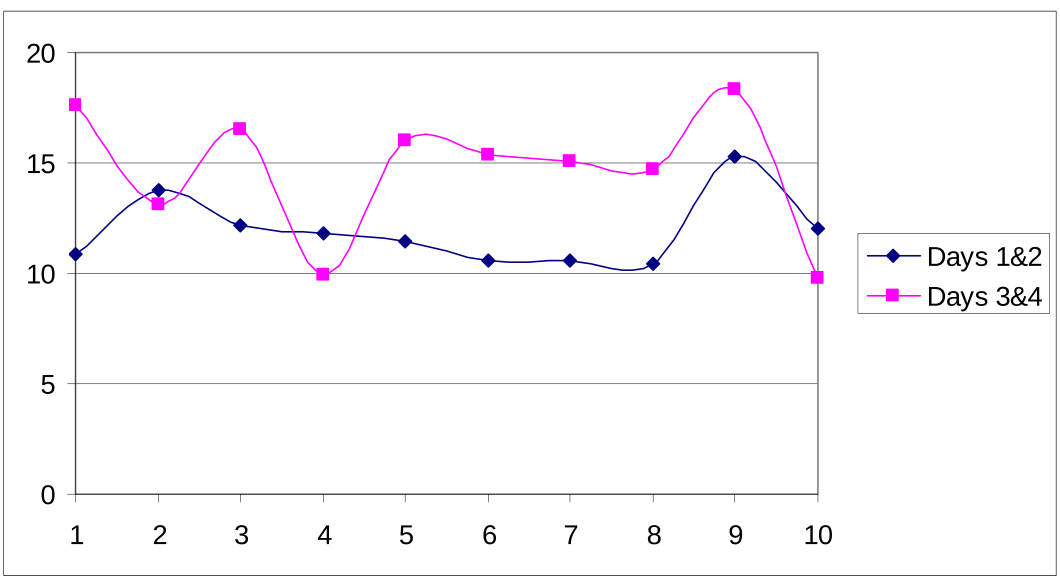
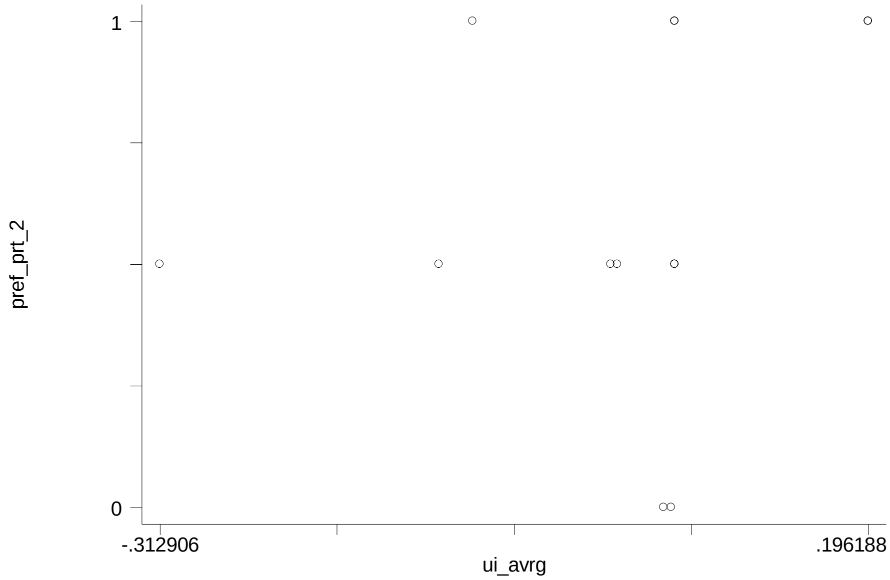
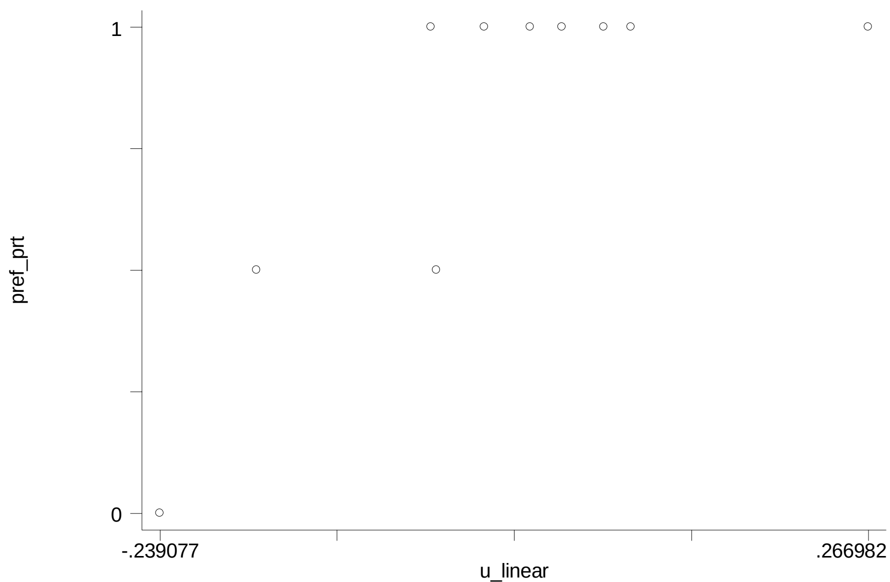


Figure 2A: Preference for Piece Rate and Ability, Ranch 1



Note: The x-axis is the individual worker's ability estimated from equation (1), y-axis is a dummy variable which takes a value of 1 if a worker prefers piece rate over hourly wages, 0 if otherwise, and 0.5 if he or she is indifferent.

Figure 2B: Preference of Piece Rate over Hourly Wages and Ability, Ranch 2:



Note: The x-axis is the individual worker's ability estimated from equation (2), y-axis is a dummy variable which takes a value of 1 if a worker prefers piece rate over hourly wages, 0 if otherwise, and 0.5 if he or she is indifferent.

Table 1A: Experiment at Ranch 1

	Day 1	Day 2
Control group (7 workers)	Started at the west (and thin) end of the block	Moved toward the middle of the block
Pay method	Hourly wages	Hourly wages
Group average number of apples on ground for control group	47.52	44.90
Treatment group (7 workers)	Started at the east (and thick) end of the block	Moved toward the middle of the block
Pay method	Hourly wages	Piece rate
Group average number of apples on the ground for test group	86.00	51.86
Highest Temperature	96F	95F
Working Hours	5:30am – 1:30pm	5:30am – 1:30pm
Break	12 – 12:30pm	12 – 12:30pm

Table 1B: Experiment at Ranch 2

	Day 1	Day 2	Day 3	Day 4	Day 5
Rows in fields	All workers started on the west (and thick) end of the block: rows 1 to 10.	Finished rows 1 to 10, and began working on odd numbered rows 11 to 30.	Finished the odd numbered rows 11 to 30; started and finished the even numbered rows 11 to 30; started even numbered rows 31 to 50.	Finished the even numbered rows 31 to 50; started even numbered rows 51 to 70.	Finished the even numbered rows 51 to 70 and finished the odd numbered rows 31 to 70.
Pay method	All are paid hourly wages.	All are paid hourly wages.	Paid hourly wages before finishing the day 2 row. Paid piece rates when starting a new (and the even) row.	All paid piece rates.	All paid piece rates.
Highest Temperature	98F	94F	84F	92F	--
Working Hours	6am -12pm	6am – 3pm	6am – 3pm	6am – 12pm	6am-3pm
Break	15 minutes	30 minutes	30 minutes	15 minutes	--
Rows for which apples on the ground are counted		Odd numbered rows 11 to 30	Even numbered rows 11 to 30	Rows worked on at the end of day 4	
Group average number of apples on ground	–	163.98	157.22	84.54	

Table 1C: Hourly Number of Trees Thinned at Ranch 1

	Raw data			Using individual row count of apples on the ground to adjust			Using the group average count of apples on the ground to adjust		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Before	After	Percent change	Before	After	Percent change	Before	After	Percent change
Control group	84.08	100.61	19.66	84.08	93.28	10.94	84.08	95.10	13.11
Test group	46.4	117.07	152.31	87.06	130.44	49.83	84.00	128	52.38
Diff-in-diff	--	--	132.65	--	--	38.89	--	--	39.27

Table 1D: Hourly Number of Trees Thinned at Ranch 2

	Raw data			Using individual row count of apples on the ground to adjust			Using the group average count of apple on the ground to adjust		
	Before	After	Percent change	Before	After	Percent change	Before	After	Percent change
All	11.01	17.85	62.10	11.58	14.32	23.72	11.89	14.64	23.17

Note: I used linear interpolation; see text for details.

Table 2A: The Productivity Effect of Piece Rates at Ranch 1

Ln	(1)	(2)	(3)	(4)	(5)	(6)
	No. trees thinned, adjusted using the group average count of apple on the ground	No. trees thinned, adjusted using the group average count of apple on the ground	No. trees thinned, adjusted using the group average count of apple on the ground	No. trees thinned, adjusted using the group average count of apple on the ground	No. trees thinned, adjusted using the individual row count of apple on the ground	No. trees thinned, adjusted using the individual row count of apple on the ground
Dummy for piece rate	.39 (.05)	.31 (.08)	.34 (.05)	.31 (.05)	.33 (.16)	.36 (.22)
Dummy for day 2	--	.12 (.08)	.11 (.04)	.12 (.04)	.13 (.16)	.11 (.16)
R-squared	.54	.58	.80	.58	.22	.22
No. of obs.	28	28	26	28	28	28
Estimation method	Ols	Ols	With extra controls	Worker fixed effects	Ols	Worker fixed effects
Within				.92		.44
Between				.23		.06
Percent change	47.7	36.3	40.50	36.3	39.1	43.3

1. Standard errors, in parenthesis, are adjusted for heteroskedasticity.
2. The control variables in column (3) include the worker's working experience (in months) at YVO, his/her age, a dummy variable for his/her marital status, and the number of his/her children.

Table 2B: The Productivity Effect of Piece Rates at Ranch 2

Dep. Variable:	Ln (number of trees thinned) adjusted using the group average count of apple on the ground							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dummy for piece rate	0.21 (0.08)	0.21 (0.07)	0.16 (0.07)	0.16 (0.09)	0.26 (0.10)	0.26 (0.09)	0.21 (0.10)	0.21 (0.10)
Dummy for day 1	--	--	-0.12 (0.11)	-0.12 (0.11)	--	--	-0.12 (0.11)	-0.12 (0.11)
Dummy for day 4	--	--	--	--	-0.10 (0.11)	-0.10 (0.10)	-0.10 (0.11)	-0.10 (0.10)
R-squared	0.18	0.18	0.21	0.21	0.20	0.20	0.23	0.23
No. of obs.	37	37	37	37	37	37	37	37
Estimation method	Ols	Worker fixed effect	Ols	Worker fixed effect	Ols	Worker fixed effect	Ols	Worker fixed effect
Within	--	0.24	--	.28	--	.27	--	0.31
Between	--	0.02	--	.02	--	.03	--	0.02
Pct change	23.75	23.73	17.35	17.35	29.87	29.65	23.09	23.10

Notes: Standard errors, in parenthesis, are adjusted for heteroskedasticity.

Table 3: Sensitivity Check for Ranch 2

	No. of obs.	Estimate, OLS	Estimate, worker fixed effects	Percentage change
Use linear interpolation	37	0.2078 (0.0978)	0.2078 (0.0992)	23.10
1.0 for thick rows	37	0.2649 (0.0990)	0.2649 (0.0998)	30.33
1.1 for thick rows	37	0.2320 (0.0982)	0.2320 (0.0994)	26.11
1.2 for thick rows	37	0.2005 (0.0977)	0.2006 (0.0992)	22.21
Bottom is 6.5/11 of a tree	37	0.1916 (0.0970)	0.1916 (0.1013)	21.12
Separate day "2.5," which refers to the 1st hour of natural day 3 and the natural day 4 hours when workers still worked on odd rows, from day 3	47	0.2855 (0.1041)	0.3176 (0.1262)	33.04
Separate day "2.5," which refers to the 1st hour of natural day 3 and the natural day 4 hours when workers still worked on odd rows, from day 3; Add controls for day 2.5	47	0.1805 (0.0762)	0.2144 (0.1339)	19.78
Add work experience, age, marriage dummy, and number of children	37	0.2078 (0.1009)	--	23.10

1. Dep. Var.: Ln (number of trees thinned), adjusted using the group average count of apple on ground.
2. Standard errors, in parenthesis, are adjusted for heteroskedasticity.

Table 4A: Variance of Workers' Productivity, Ranch 1

Using the group average count of apples on the ground to adjust	Mean number of trees thinned per hour, standard deviation in parentheses	
	Before	After
Control group	84.08 (12.07)	95.06 (18.68)
Test group	83.97 (12.14)	127.76 (12.55)

Table 4B: Variance of Workers' Productivity, Ranch 2

Using the group average count of apples on the ground to adjust	Mean number of trees thinned per hour, standard deviation in parentheses	
	Before	After
All workers	11.88 (1.57)	14.64 (2.92)

Table 5A: Quality, Ranch 1

	Quality	Quality
Dummy for piece rate	0.07 (0.11)	-0.07 (0.17)
Day 2 dummy	-1.57e-17 (0.09)	0.07 (0.12)
R-squared	0.03	0.0029
No. of obs.	28	28
Estimation method	Ols	Worker fixed effects

Note:

1. Quality was judged on a 1-5 scale:
   1 Worker leaves 99 percent or more of spurs thinned well.
   2 Worker leaves 95 percent or more of spurs thinned well. (1 of 20 is bad)
   3 Worker leaves 90 percent or more of spurs thinned well. (2 of 20 are bad)
   4 Worker leaves 85 percent or more of spurs thinned well. (3 of 20 are bad)
   5 Worker leaves less than 85 percent of spurs thinned well. (3 or more of 20 are bad)
2. Standard errors, in parenthesis, are adjusted for heteroskedasticity.

Table 5B: Quality, Ranch 2

	Quality	Quality	Quality	Quality
Dummy for piece rate	0.17 (0.15)	0.23 (0.15)	0.30 (0.20)	0.30 (0.19)
Dummy for day 1	--	--	-0.16 (0.18)	-0.27 (0.21)
Dummy for day 4	--	--	-0.43 (0.21)	-0.39 (0.20)
R-squared	0.04	0.04	0.17	0.16
No. of obs.	37	37	37	37
Estimation method	Ols	Worker fixed effects	Ols	Worker fixed effects

1. Standard errors, in parenthesis, are adjusted for heteroskedasticity.

Table 6: Preference for Piece Rate as a Function of Ability

	Ranch 1	Ranch 2
	Preference for piece rate	Preference for piece rate
Ability	0.62 (0.51)	1.93 (0.73)
With controls of age, dummy for marriage, number of children	--	--
Work experience at YVO	--	--
(Pseudo) R-squared	0.24	0.33
No. of observations	13	10
Estimation method	Ols	Ols

Notes:
1. Ability is measured using the worker fixed effect in Equation (1) for Ranch 1, and (2) for Ranch 2.
2. Standard errors, in parenthesis, are adjusted for heteroskedasticity.

Figure A1: Worker-level Hourly Number of Trees Thinned at Ranch 1, Adjusted for Thickness of Apples Using Individual Row's Apples on the Ground

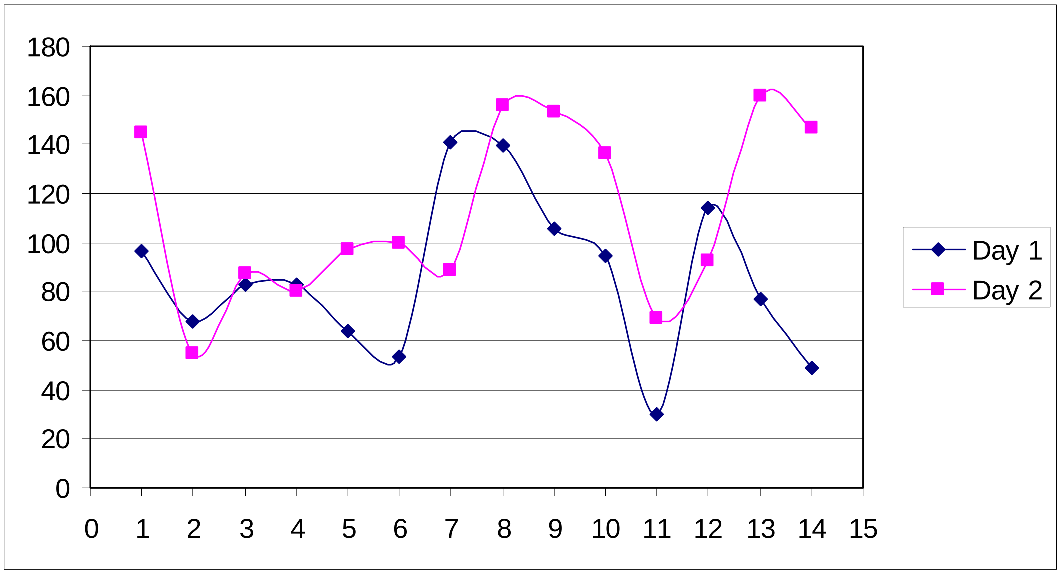


Figure A2: Worker-level Hourly Number of Trees Thinned at Ranch 2, Adjusted for Thickness of Apples Using Individual Row's Apples on the Ground

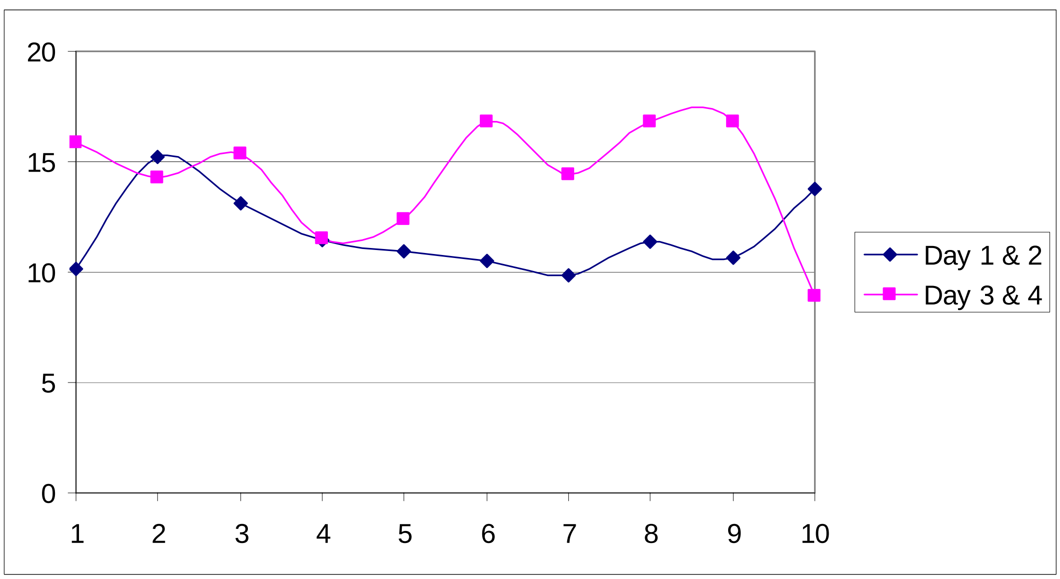


Figure A3: Worker-level Hourly Number of Trees Thinned at Ranch 2 for day 2 & 3, Adjusted for Thickness of Apples Using Group Average Count of Apples on the Ground

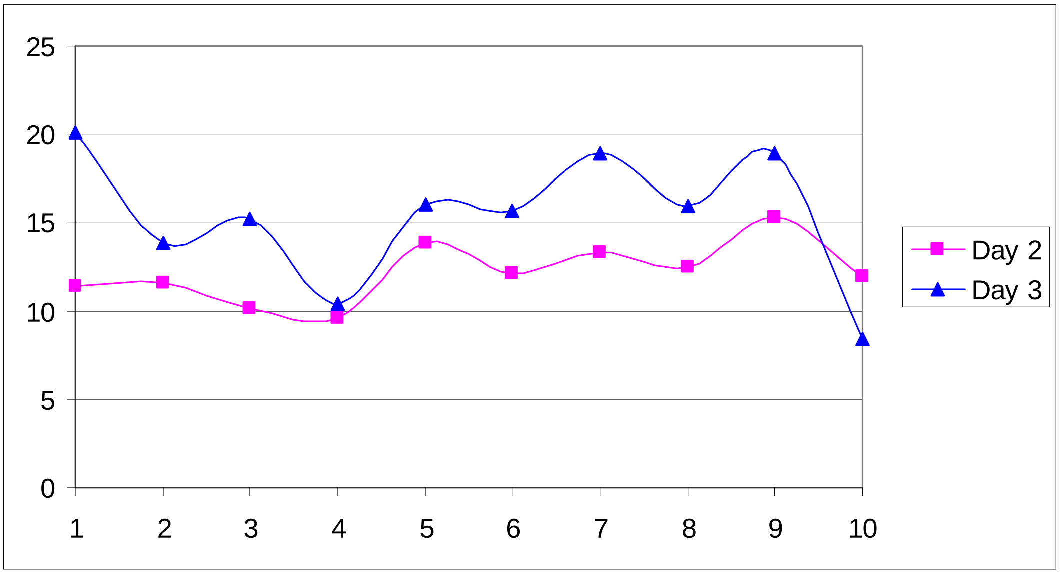


Table A1: Variance of Workers' Productivity at Ranch 1

	Using the individual row count of apples on the ground to adjust	
	Before	After
Control group	83.15 (28.54)	92.25 (26.93)
Test group	86.09 (37.52)	129.01 (35.05)

Note: The entry is the mean number of trees thinned per hour. The entry in the parenthesis is the standard deviation.

Table A2: Variance of Workers' Productivity at Ranch 2

	Using the individual row count of apples on the ground to adjust	
	Before	After, day 1
All workers	11.58 (1.76)	14.32 (2.64)

Note: The entry is the mean number of trees thinned per hour. The entry in the parenthesis is the standard deviation.